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BURN

AN INTERACTIVE MODEL TO SIMULATE THE IMPACTS OF FIRE

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School of Renewable Natural Resources
University of Arizona, Tucson

February 15, 1982

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PREFACE

The report presented herein has been prepared by the authors as required under the provisions of Cooperative Agreement No. 16-873-CA, entitled Development of a Prototypical Fire Module.

To a large extent, this report can be considered a supplement to an earlier report prepared by the authors, entitled AN INTERACTIVE SYSTEM OF ECOSYSTEM SIMULATION MODELS, dated September 1, 1980, as required under the provisions of the various supplements to Cooperative Agreement No. 16-624-CA. The model described herein has been developed according to the design criteria outlined in this latter report, and it has been formulated to conform with the structure of the models discussed in the report.

The prototyical version of BURN described herein represents developments as of December 31, 1981. Subsequent refinements in design and operation of this model have not been reported upon.

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BURN

AN INTERACTIVE MODEL TO SIMULATE THE IMPACTS OF FIRE

Introduction

To aid forest fire specialists and land use planners in estimating impacts of fire on various components of southwestern ponderosa pine forest ecosystems, a prototypical computer simulation model, called BURN, has been developed to obtain estimates of benefits or losses after fire on the following ecosystem components; vegetative components, including mortality of forest overstories, regeneration of tree species, and production of herbaceous understories; wildlife components, including changes in populations and effects on habitat qualities; and hydrologic components, including streamflow and water quality. The prototypical version of BURN is written in ANSI Standard FORTRAN, and it is currently operational on the University of Arizona's DEC-10 computer in an interactive mode. Core requirements of BURN are relatively small, requiring 15-20 K words.

As mentioned above and currently structured, BURN is applicable to southwestern ponderosa pine forests. However, the conceptual framework is general and, if desired, can be extended to other ecosystems as well.

Formulation

The general approach followed in the formulation of BURN was to assume that changes in an ecosystem due to fire can be thought of as flows of benefits (increases) or losses (decreases) through time after the fire. By contrasting flows of benefits or losses against a control (an unburned area), so-called time-trend response functions can be defined (Lowe 1975, Lowe et al. 1978). These functions, which are graphical representations

of the potential benefits or losses which occur after fire, formed a basis for the formulation of BURN, as described below.

Development of Time-Trend Response Functions

For each ecosystem component investigated in BURN, a set of index values were derived to characterize the resource. For example, to describe the composition of herbaceous understories, the frequency of occurrence of herbaceous plants was determined in cylindrical plots 9.8 feet in diameter and 5 feet high. To ascertain mule deer, elk, and cottontail population numbers, pellets were counted and cleared from 0.01-acre circular plots. And, to quantify water quality, specific chemical constitutents were analyzed by the Department of Soils, Water, and Engineering at the University of Arizona.

To present the source data in a consistent fashion, the index values derived (1) by sampling for a given attribute at different points in time after fire on a study area or (2) from sampling a given attribute on a series of study areas representing different fire histories were divided by index values obtained on a control area. The result was unitless value, with the value of the control always 1.0. Assuming that ecosystem components would respond in a same manner to fluctuations in weather conditions, time of year, and cyclic alterations on each study area, the ratios were considered indicators of changes to fire only.

Graphs were designed for each attribute investigated, with the ratios plotted on the Y-axis and time after fire on the X-axis. The control was represented by a horizontal line at the ratio of 1.0 and, as mentioned above, it was considered an indicator of conditions as they would have been with no fire. Schematic curves represented flows of benefits or losses for an arbitrarily selected time period of 20-years after fire. The curves were

drawn with respect to the plotted ratios and were guided by the author's backgrounds.

If a curve was above the horizontal line representing the control line, it was considered a benefit, while a curve below the control line was a loss. If a ratio was not significantly different from the control value, no change in benefits or losses was assumed. Again, by definition, these curves are referred to as time-trend response functions.

To illustrate, time-trend response functions for ground squirrel and for all species of nongame birds associated with southwestern ponderosa pine forest are shown in figures 1 and 2, respectively. Ground squirrel populations decline after fire, reaching their lowest 3 years after fire, then increased to nearly 2.5 times the control 7 years after fire. After 20 years, ground squirrel populations drop to the control level. Total nongame birds numbers react differently to fire than ground squirrels. Total nongame birds increase during the first year after fire, then decrease to below the prefire level for the remainder of the 20-year evaluation period.

Development of an Index of Benefits or Losses

For assessment purposes, time-trend response functions were converted to an index of benefits or losses (Lowe 1975, Lowe et al. 1978) by initially determining streams of annual ratio values. The technique converts the flows of benefits or losses (the streams of annual ratios) to annuities, or equal annual returns from the resource. While annuities are normally thought ofin terms of dollars, the concept is equally applicable to nonmonetary flows. Annuities were calculated from:

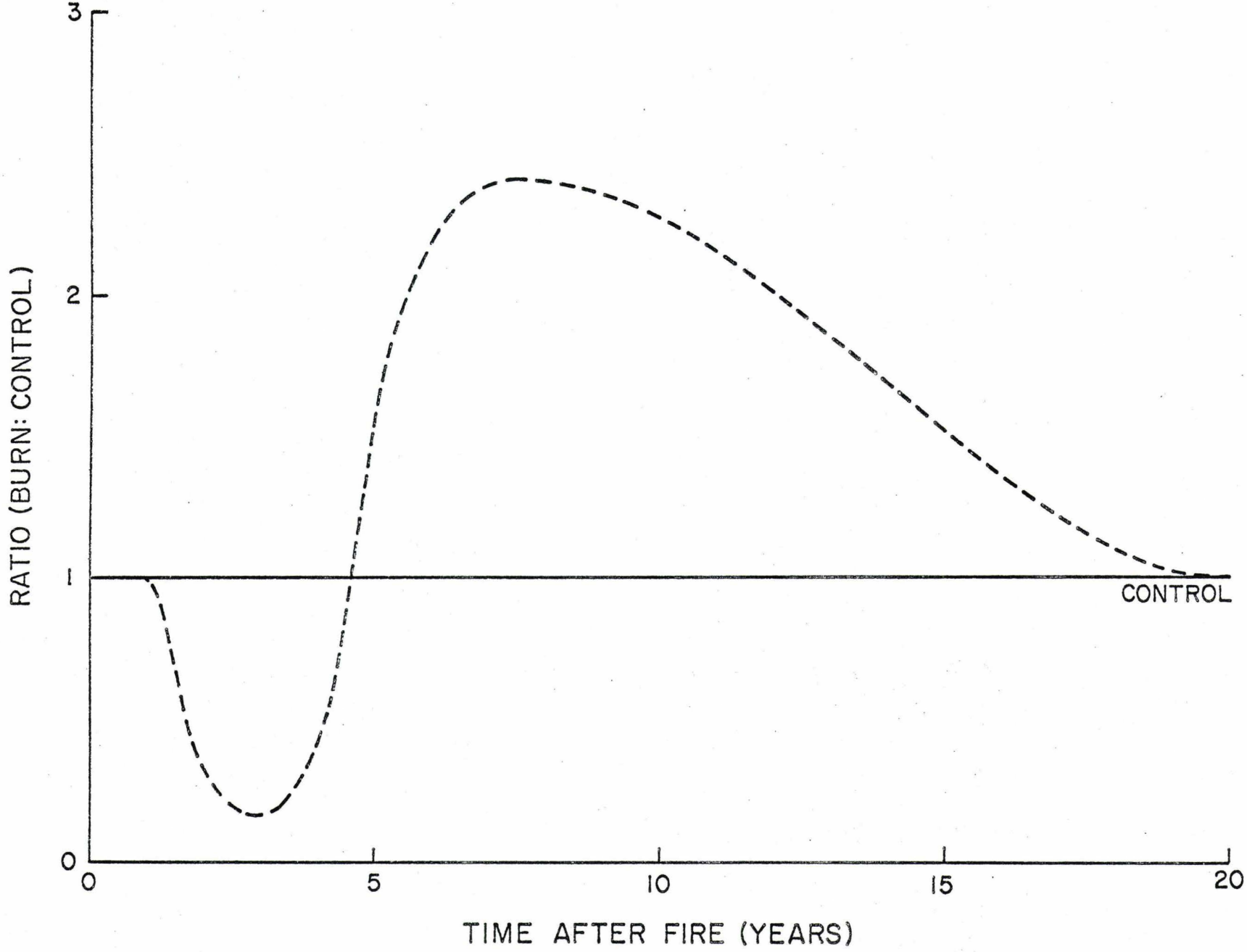

Figure 1. - Time-trend response function for ground squirrel.

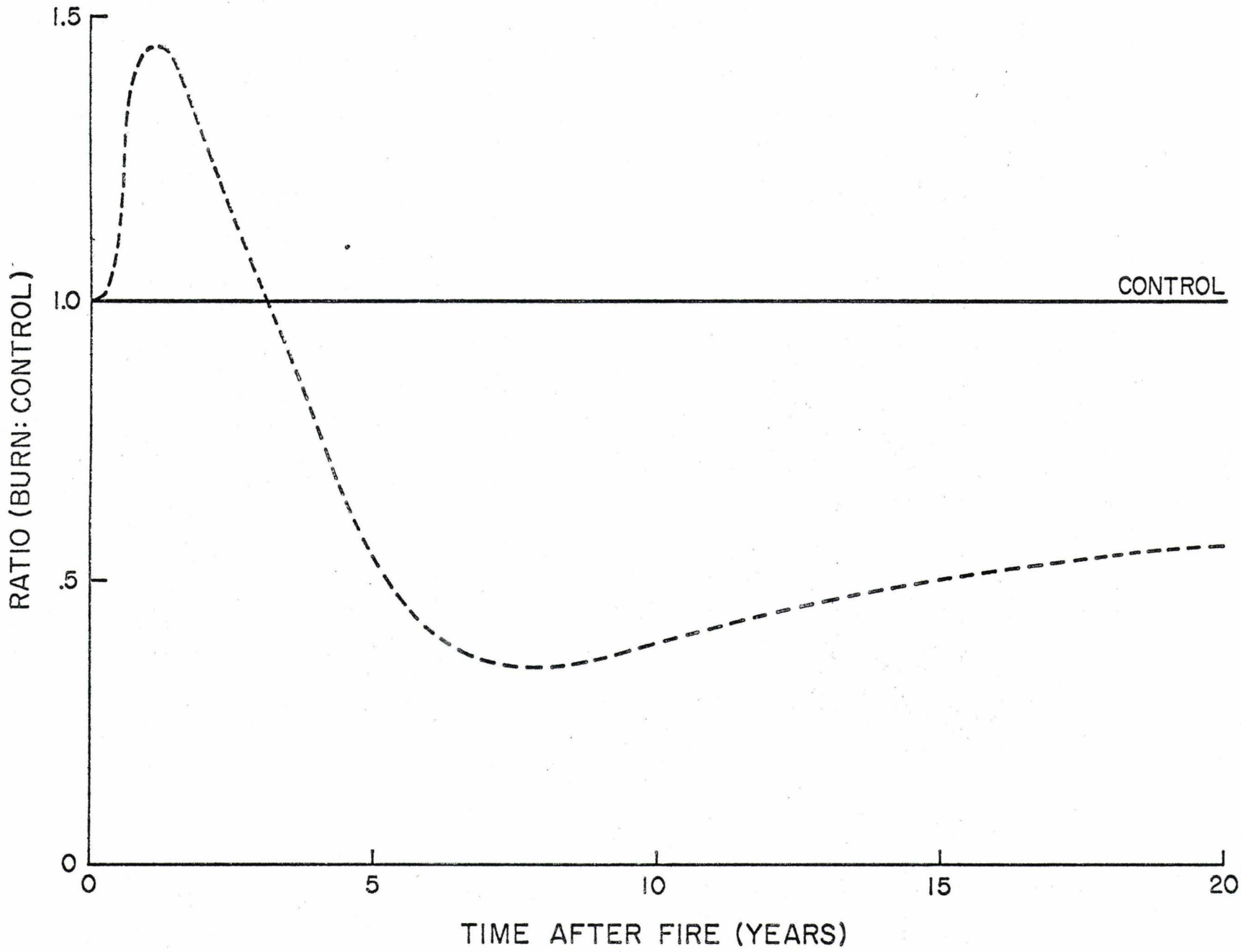

Figure 2. - Time-trend response function for all species of birds.

$$a = \frac{Vo(i(1+i)^n}{(1+i)^{n-1}} \quad (1)$$

where a = the annuity;

Vo = the present net worth, or the total of all (yearly) values from the time-trend response functions discounted to time zero;

i = the discount (interest) rate; and

n = the number of years to analysis.

Present net worth (Vo) was determined from:

$$Vo = \sum_{n=1}^{20} \frac{Vn}{(1+i)^n} \quad (2)$$

Where Vn = the value of the ratio (Y-axis) taken from the time-trend response functions for individual years in the analysis (1 to 20).

The annuities allow a condensation of annual ratio values into a single annual index value (Lowe et al. 1978). Theoretically, the annuity value of 1.0 is indifferent at the stated discount rate to the annuity each year, or to the actual streams of annual ratios over a similar time period. Since the ratio for the control is 1.0 for each year, the annuity is also 1.0. Annuity values that are higher or lower than 1.0 indicate benefits or losses, respectively.

Annuities calculated for 20-year periods are highly responsive to the discount rate employed. In essence, the discount rate determines how much weight is given to the different annual ratios. The greater the discount rate, the more heavily future yields are discounted. If a 5% discount rate is used, ratios for 1 year after fire are weighed 2.5 times as heavily as ratios for 20 years after fire. However, if a 10% discount rate is used, ratios for 1 year after fire are weighed more than 6 times has heavily as ratios for 20 years after fire.

Attribute Measured

For each ecosystem component in the prototypical version of BURN, a number of attributes have been considered by various index values. The attributes measurements were derived from secondary data sources, as described below.

Vegetative Component

1. Ponderosa Pine Tree Mortality

   Trees were inventories on study areas using a systematic set of 30 0.1-acre sample plots established on each study area (Campbell et al. 1977). All trees on each plot were tallied, and 4 trees from each plot were measured for size class (sapling, pulpwood, and sawtimber) determination. Periodic reinventories furnished a basis to assess the rate of ponderosa pine tree mortality in comparison to naturally occurring tree mortality. Additional information on mortality was obtained from Davis et al. (1968), Pearson et al. (1972), and Ffolliott et al. (1977).

2. Ponderosa Pine Tree Regeneration

   Survival of ponderosa pine seedlings naturally started or planted on burned areas was measured on mil-acre sample plots systematically established on the study areas (Ffolliott et al. 1977, Campbell et al. 1977). This survival rate was then compared to the survival of pondersoa pine seedlings on unburned sites.

3. Production of Herbaceous Understories

   Annual herbage production was determined by clipping and weighing the plant material or by weight-estimates on sample plots systematically established on the study areas (Davis et al. 1968,

Pearson et al. 1972, Ffolliott et al. 1977, Campbell et al. 1977). No attempt was made to describe the effects of fire on the production of herbaceous understories by plant species or species grouping (grasses, forbs, half-shrubs, etc.) in the development of a prototye of BURN.

Wildlife Component

1. Mule Deer Populations

Populations of mule deer were indexed by fecal pellets counted and cleared from 0.01-acre circular plots centered over sample points within measurement grids established on the study areas (Lowe et al. 1978). Summer-fall and winter-spring populations were indexed.

2. Elk Populations

Populations of elk were indexed by fecal pellets, following a similar procedure as used for mule deer populations (Lowe et al. 1978). Again, summer-fall and winter-spring populations were indexed.

3. Abert Squirrel Populations

No attempt was made to describe the effects of fire on Abert squirrel populations in the prototypical version of BURN. From a mensurational standpoint, it is quite difficult to index populations from readily available measurement values. Presumably, and dependent upon the intensity and extent of a fire, Abert squirrel populations can be affected by fire.

4. Cottontail Populations

Populations of cottontail were indexed by fecal pellets, following

a similar method as used for mule deer (Lowe et al. 1978). Summer-fall and winter-spring populations were indexed.

5. Rodent Populations

Populations of mice, ground squirrels, and chipmunks, expressed in terms of densities, were estimated by dividing the numbers of animals caught with snap traps at sample points within measurement grids established on the study areas, trapping for 3 consecutive days during summer, by the areas sampled (Lowe et al. 1978). Areas sampled were determined from home range values taken from the literature: 1.7 acres for mice (King 1968), 6.4 acres for ground squirrels (Gordon 1943), and 2.2 acres for chipmunks (Gordon 1943).

6. Nongame Bird Populations

Populations of nongame birds were determined by systematically walking on the study area in early morning, and then mapping the location of each bird species observed (Lowe et al. 1978). Observations were made for 2 consecutive days in the spring, with each measurement grid walked twice a day. Densities of nongame bird populations, expressed in terms of birds per 100 acres, were estimated by dividing the numbers of birds seen by the areas sampled, the latter being determined from mapping. Nongame bird populations were grouped into feeding categories for further refinement. These feeding categories, after Brock and Lynch (1970) included: tree-foliage-searching birds, timber-gleaning birds, ground- and brush-foraging birds, flycatching birds, timber-drilling birds, and aerial flycatching birds. Total nongame bird populations were also measured.

7. Frequency of Occurrence of Browse and Forage Species

Following a procedure described by Aldous (1944), the frequency of occurrence of important browse and forage species was estimated on 0.01-acre plots, 5 feet high, centered over sample points within measurement grids established on the study areas (Lowe et al. 1978). Browse and forage species were considered present or absent within the cylindrical plot. In the prototypical version of BURN, the following browse and forage species have been considered: ponderosa pine, buckbrush, deervetch, fleabane, and buckwheat.

8. Ground Cover

Using sample plots and transects located on the study areas, ground cover was determined (Pearson et al. 1972, Campbell et al. 1977, Lowe et al. 1978). Forge basal area, grass basal area, litter (dead organic materials), bare ground, and rock were estimated.

Hydrologic Component

1. Streamflow

Annual streamflow amounts were measured by water-stage recorders at control sections located at the outlets of the study watersheds (Campbell et al. 1977). Due to the limited streamflow records available, extensions of streamflow response to fire through the 20-year evaluation period are subjective and judgemental. However, the relative orders of magnitude for the annual ratio values used in calculating the annuities are throught to be appropriate.

2. Water Quality

Water samples collected before and after fire on the study areas were analyzed by the Department of Soils, Water, and Engineering at the University of Arizona. Specific constituents assessed were: calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^{+}), cloride (Cl^{-}), sulfate (SO_4^{-}), bicarbonate (HCO_3^{-}), fluoride (F^{-}), nitrate (NO_3^{-}), pH, total soluble salts, and electrical conductivity (Sims 1979, Sims et al. 1982). Additional information on water quality was obtained from Campbell et al. (1977).

Flowchart

The conceptual flow of activites that are followed in executing the prototyical version of BURN to obtain estimates of benefits or losses after fire is illustrated in figure 3. Through inputs of forest type, evaluation component, fire intensity, evaluation period, and discount rate, a fire impact index, or annuity value, is calculated. Then, the simulation exercise can be recycled, if desired, to analyze a series of discount rates, evaluation periods, fire intensities, and evaluation components.

A summary display is output at the end of the simulation exercise, presenting estimates of benefits or losses after fire on ecosystem components in terms of annuities.

Application of Model

Perhaps the best way to illustrate the application of BURN in estimating the impacts of fire on various components of southwestern ponderosa pine forest ecosystems is through an example. For purposes of illustration, a hypothetical tract of southwestern ponderosa pine forest land will be

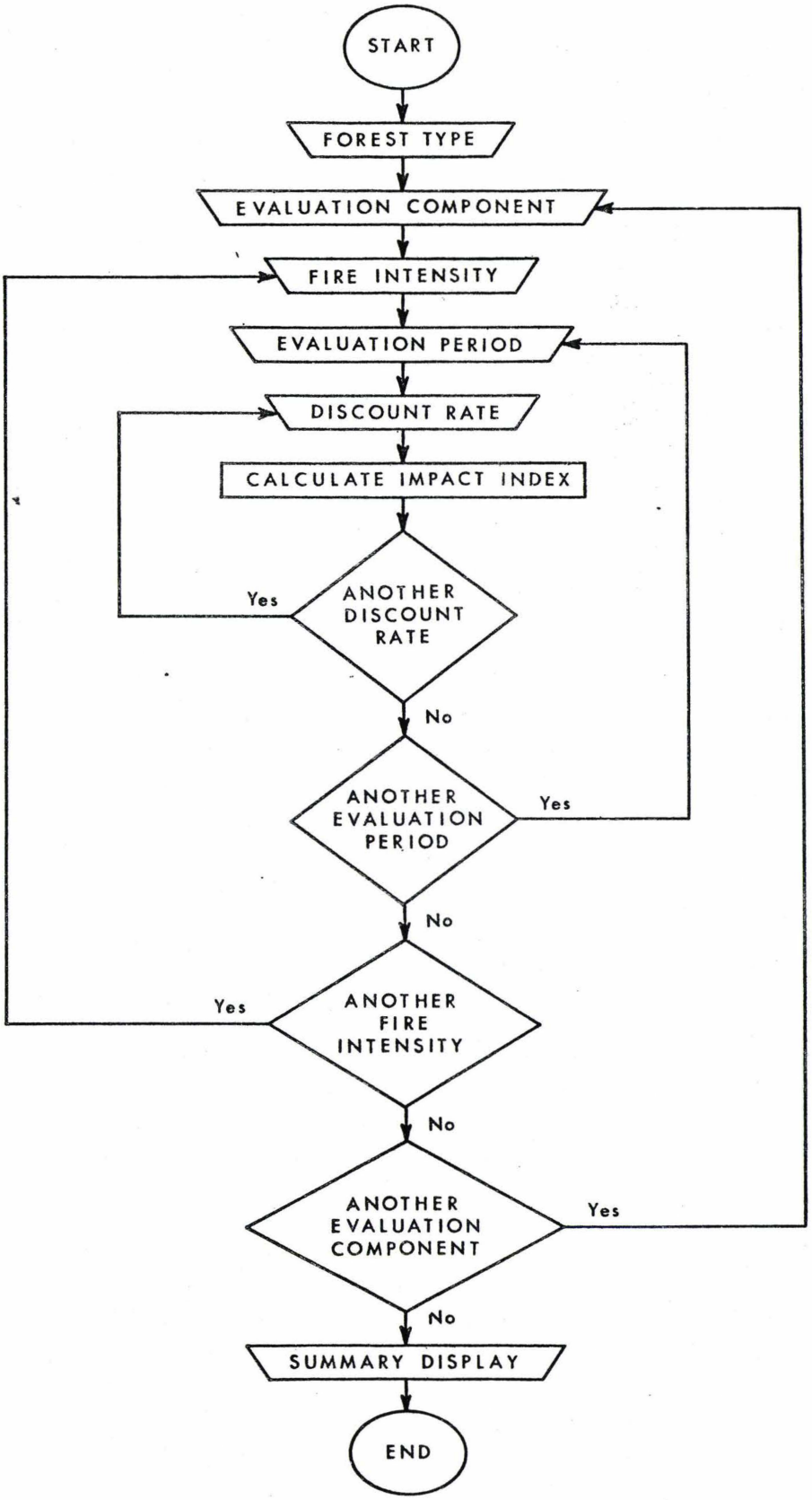

Figure 3. - Flow of activities in the prototypical version of BURN.

examined in terms of assessing the benefits or losses on specific ecosystem components after a fire. In the example we look at the effects of fire on elk populations which use the area in the summer and fall.

To obtain predictions of the impact index the user must respond to interactive statements and questions that structure the simulation exercise and describe conditions. The operation of BURN begins by presenting the user three forest types with numberic keys and asking them to "ENTER NUMBER OF FOREST TYPE YOU WISH TO EVALUATE" (Figure 4). For the example, the response was "1" indicating ponderosa pine. The user is then presented a list of ecosystem components that may be evaluated. Again the individual components have numbers associated with them. The user is told to "ENTER NUMBER OF COMPONENT YOU WISH TO EVALUATE". The response is "2" indicating they wish to work with the wildlife component. The program next presents the user a list of wildlife attributes. Each of these may have the impact index computed for it. In some cases such as rodents, nongame birds, browse and forage species, and ground cover there are more detailed lists of attributes which are presented the user should they select them. For the example, we select elk (summer and fall use) from the list by responding with "3" to the directive of "ENTER NUMBER OF ATTRIBUTE YOU WISH TO EVALUATE". The model next presents the user a list of fire intensities (each with a numeric value) and directs them to "ENTER NUMBER OF FIRE INTENSITY OPTION". For the example, the fire intensity was at least 5,000 btu/sec/ft which was conveyed to the model with a response of "2". The length of the post-burning evaluation period is next requested. This is the number of years from the occurance of the fire. The model requests this by typing to the user "POST-BURNING EVALUATION PERIOD IN YEARS (CR GIVES:20)?". The CR mentioned is the carriage return key on the terminal keyboard. By depressing this key

```
BURN:  FOREST TYPES ARE:

  1-PONDEROSA PINE                          2-MIXED CONIFER
  3-PINYON-JUNIPER

ENTER NUMBER OF FOREST TYPE YOU WISH TO EVALUATE   1

ECOSYSTEM EVALUATION COMPONENTS ARE:

  1- VEGETATIVE COMPONENT                   2- WILDLIFE COMPONENT
  3- HYDROLOGIC COMPONENT

ENTER NUMBER OF COMPONENT YOU WISH TO EVALUATE   2

ATTRIBUTES ARE:

  1- MULE DEER (SUMMER/FALL USE)            2- MULE DEER (WINTER/SPRING USE)
  3- ELK (SUMMER/FALL USE)                  4- ELK (WINTER/SPRING USE)
  5- ABERT SQUIRREL POPULATIONS             6- COTTONTAIL POPULATIONS
  7- RODENT POPULATIONS (LIST)              8- NONGAME BIRD POPULATIONS (LIST)
  9- BROWSE AND FORAGE SPECIES (LIST)      10- GROUND COVER (LIST)

ENTER NUMBER OF ATTRIBUTE YOU WISH TO EVALUATE   3

FIRE INTENSITY OPTIONS ARE:

  1- LESS THAN 5,000 BTU/SEC/FT             2- AT LEAST 5,000 BTU/SEC/FT
  3- OVER 10,000 BTU/SEC/FT

ENTER NUMBER OF FIRE INTENSITY OPTION   2

POST-BURNING EVALUATION PERIOD IN YEARS (CR GIVES:20) ?

DISCOUNT RATE IN PERCENT (CR GIVES: 5) ?

IMPACT INDEX FOR ELK (SUMMER/FALL USE)          IS   1.5

ANOTHER DISCOUNT RATE(YES OR NO, CR GIVES: NO) ?

ANOTHER POST-BURNING EVALUATION PERIOD(YES OR NO, CR GIVES: NO) ?

ANOTHER FIRE INTENSITY(YES OR NO, CR GIVES: NO) ?

ANOTHER ECOSYSTEM COMPONENT(YES OR NO, CR GIVES: NO) ?


SUMMARY:
                    EVALUATION   DISCOUNT
FOREST    FIRE       PERIOD       RATE     IMPACT
 TYPE  INTENSITY    (YEARS)     (PERCENT)  INDEX      ATTRIBUTE

  1        2          20           5        1.5      ELK (SUMMER/FALL USE)
```

Figure 4. - A hypothetical example of BURN

the program automatically assumes a default value of 20. The user may type 20 as a response if they so desire. For the example, we use the default value of 20 years by depressing the carriage return key. The discount rate is next requested in percent. Again, a default value is given, in this case its value is 5 percent. For the example we elect to utilize this number and consequently depress the CR key. This finishes the input of information required to compute the impact index. For the example, the impact index is computed and presented as "IMPACT INDEX FOR ELK (SUMMER/FALL USE) IS 1.5". This shows a benefit to exist for elk populations using the area in the summer and fall. As mentioned before an impact index greater than 1.0 is a benefit.

The user is now asked "ANOTHER DISCOUNT RATE (YES OR NO, CR GIVES: NO)?". If desired the user might input additional rates and have associated values computed for the impact index. The values of all other parameters would remain the same. For the example, we do not wish to compute the impact index for other rates and signify this to the program by depressing the CR key. Next, the user is asked "ANOTHER POST-BURNING EVALUATION PERIOD (YES OR NO, CR GIVES: NO)?". Another period is not desired resulting in the CR key again being used. "ANOTHER FIRE INTENSITY (YES OR NO, CR GIVES: NO)?" is now presented the user with their response of depressing the CR key as they do not wish to examine the effect of other fire intensities. Once more a question is presented the user. This time they are asked "ANOTHER ECOSYSTEM COMPONENT (YES OR NO, CR GIVES: NO)?". A positive response to this allows the user to select another ecosystem component and cycle through the model again. For the example this is not desired and the CR key is again depressed signifying a negative response.

At this point the model presents a summary of its operation to the user. For the example there was only one value of the impact index computed and

consequently there is only one line in the summary. The summary contains as many lines as there are values computed for the impact index.

Interactions with Other Models

The prototype version of BURN is part of family of interactive computer models being developed to help natural resource managers and land use planners in evaluating the impacts of land management practices and natural events. This family incudes four general modules: FLORA for estimating responses of forest overstories, herbaceous understories, and organic materials; FAUNA for evaluating animal habitats, carrying capacities, and population dynamics; WATER for assessing streamflow, sedimentation, and chemical quality; and SUPPORT for assessing the effects of fires and storms. BURN is a component of SUPPORT with interfaces to other models in the family.

Future Developments

Future developmental work involving BURN will consist of extending the basic structure of the simulator to other forest types.

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APPENDIX A

BURN

PROGRAM LISTING AND FLOWCHART

```
      1            C        PROGRAM          BURN
      2            C
      3            C        DOCUMENTATION    CONTAINED IN REPORT TO USDA FOREST SERVI
CE ENTITLED
      4            C                         INTERACTIVE PROGRAM TO SIMULATE THE EFFE
CTS
      5            C                         OF FIRE, WILLIAM O. RASMUSSEN AND PETER
F.
      6            C                         FFOLLIOTT, SRNR,U.OF ARIZ.,FEB.1982.
      7            C
      8            C        INPUT            TERMINAL---CONVERSATIONAL
      9            C                         ASSOCIATED DATA FILES------BURN.001 AND
BURN.002
     10            C
     11            C        OUTPUT           TERMINAL
     12            C
     13            C        INSTALLATION     UNIVERSITY OF ARIZONA (DEC-10)
     14            C
     15                  INTEGER VALU,FOREST,BIRD,RODENT,FIRE,RATE,YEARS,COMPNT(6,4
3),BROWS,COVER
     16                  DIMENSION FORMAT(80),V(20,43)
     17            C       VALU IS NUMBER OF ATTRIBUTE TO EVALUATE
     18                    OPEN(UNIT=1,DEVICE='DSK',FILE='BURN.001')
     19                    OPEN(UNIT=2,DEVICE='DSK',FILE='BURN.002')
     20                    OPEN(UNIT=20,DEVICE='DSK',FILE='BURN.XXX')
     21                    IOUT=5
     22                    IIN=5
     23                    READ(1,2180)COMPNT
     24                    READ(2,2170)FORMAT
     25                    DO 10 I=1,43
     26                       READ(2,FORMAT)(V(J,I),J=1,20)
     27                10     CONTINUE
     28                20 CONTINUE
     29            C       ASK FOR FOREST TYPE
     30                    WRITE(IOUT,2000)
     31                    WRITE(IOUT,2010)
     32                    READ(IIN,2020)FOREST
     33            C       CHECK ON TYPE
     34                    IF(FOREST.NE.2.AND.FOREST.NE.3) GO TO 30
     35                       WRITE(IOUT,2030)FOREST
     36                       GO TO 20
     37                30 CONTINUE
```

```
38                IF(FOREST.LT.1.OR.FOREST.GT.3) GO TO 20
39          C     ASK WHICH ECOSYSTEM COMPONENT
40             40 WRITE(IOUT,2190)
41          C     OBTAIN ECOSYSTEM COMP. NUMBER
42                READ(IIN,2020) IECO
43          C     CHECK VALIDITY
44                IF(IECO.LT.1.OR.IECO.GT.3) GO TO 40
45                GO TO (50,60,120),IECO
46          C     VEGETATIVE COMPONENT
47             50 WRITE(IOUT,2200)
48          C     WHICH ONE
49                READ(IIN,2020) IVEGA
50          C     CHECK VALIDITY
51                IF(IVEGA.LT.1.OR.IVEGA.GT.3) GO TO 50
52          C     ASSIGN ATTRIBUTE NUMBER
53                VALU=IVEGA+40
54          C     ON WITH QUESTIONS
55                GO TO 140
56          C     WILDLIFE COMPONENT
57             60 WRITE(IOUT,2210)
58          C     WHICH ONE
59                READ(IIN,2020) IWILD
60          C     CHECK VALIDITY
61                IF(IWILD.LT.1.OR.IWILD.GT.10) GO TO 60
62          C     NEED A RODENT LIST ?
63                IF(IWILD.EQ.7) GO TO 80
64          C     NEED A BIRD LIST ?
65                   IF(IWILD.EQ.8) GO TO 90
66          C     NEED A BROWSE LIST?
67                      IF(IWILD.EQ.9) GO TO 100
68          C     NEED A GROUND COVER LIST ?
69                         IF(IWILD.EQ.10) GO TO 110
70          C     CHECK FOR ABERT SQUIRREL
71                            IF(IWILD.EQ.5) GO TO 70
72          C     ASSIGN ATTRIBUTE NUMBER
73                               VALU=IWILD
74          C      ON WITH QUESTIONS
75                               GO TO 140
76          C     FOUND ABERT SQUIRREL
77             70              WRITE(IOUT,2070) IWILD
78                               GO TO 60
79          C     RODENT LIST
```

```
 80              80          WRITE(IOUT,2220)
 81                            READ(IIN,2020) RODENT
 82            C       CHECK VALIDITY
 83                            IF(RODENT.LT.1.OR.RODENT.GT.3) GO TO 80
 84            C       ASSIGN ATTRIBUTE NUMBER
 85                            VALU=RODENT+25
 86            C       ON WITH QUESTIONS
 87                            GO TO 140
 88            C       BIRD LIST
 89               90         WRITE(IOUT,2230)
 90                            READ(IIN,2020)BIRD
 91            C       CHECK VALIDITY
 92                            IF(BIRD.LT.1.OR.BIRD.GT.7) GO TO 90
 93            C       ASSIGN ATTRIBUTE NUMBER
 94                          VALU=BIRD+18
 95            C       ON WITH QUESTIONS
 96                          GO TO 140
 97            C       BROWSE LIST
 98              100     WRITE(IOUT,2240)
 99                        READ(IIN,2020) BROWS
100            C       CHECK VALIDITY
101                       IF(BROWS.LT.1.OR.BROWS.GT.5) GO TO 100
102            C       ASSIGN ATTRIBUTE NUMBER
103                       VALU=BROWS+8
104            C       ON WITH QUESTIONS
105                       GO TO 140
106            C       GROUND COVER LIST
107              110 WRITE(IOUT,2250)
108                     READ(IIN,2020) COVER
109            C       CHECK VALIDITY
110                     IF(COVER.LT.1.OR.COVER.GT.5) GO TO 110
111            C       ASSIGN ATTRIBUTE NUMBER
112                     VALU=COVER+13
113            C       ON WITH QUESTIONS
114                     GO TO 140
115            C       HYDROLOGIC COMPONENT
116              120 WRITE(IOUT,2260)
117                     READ(IIN,2020) INHY
118            C       CHECK VALIDITY
119                     IF(INHY.LT.1.OR.INHY.GT.2) GO TO 120
120                     IF(INHY.EQ.2) GO TO 130
121            C       ASSIGN ATTRIBUTE NUMBER
```

```
122                   VALU=INHY+28
123           C       ON WITH QUESTIONS
124                   GO TO 140
125           C       WATER QUALITY LIST
126             130 WRITE(IOUT,2270)
127                 READ(IIN,2020) INWQ
128           C       CHECK VALIDITY
129                 IF(INWQ.LT.1.OR.INWQ.GT.11) GO TO 130
130           C       ASSIGN ATTRIBUTE NUMBER
131                 VALU=INWQ+29
132           C       ON WITH QUESTIONS
133                 GO TO 140
134           C       ASK FOR FIRE INTENSITY
135             140 WRITE(IOUT,2050)
136                 WRITE(IOUT,2060)
137                 READ(IIN,2020)FIRE
138                 IF(FIRE.EQ.2) GO TO 150
139           C       FIRE OPTION OUT OF RANGE
140                   WRITE(IOUT,2070)FIRE
141                   GO TO 140
142             150 CONTINUE
143           C       ASK FOR EVALUATION PERIOD
144                 WRITE(IOUT,2080)
145                 READ(IIN,2020)YEARS
146                 IF(YEARS.EQ.0) YEARS=20
147                 IF(YEARS.GT.0.AND.YEARS.LE.20) GO TO 160
148           C       YEARS OUT OF RANGE
149                   WRITE(IOUT,2040)
150                   GO TO 150
151             160 CONTINUE
152           C       ASK FOR RATE
153                 WRITE(IOUT,2090)
154                 READ(IIN,2020)RATE
155                 IF(RATE.EQ.0) RATE=5
156                 IF(RATE.GT.0.AND.RATE.LE.100) GO TO 170
157           C       RATE OUT OF RANGE
158                   WRITE(IOUT,2100)
159                   GO TO 160
160             170 CONTINUE
161           C                 COMPUTE INDEX
162                 SUM=0.0
163                 FLOATI=FLOAT(RATE)/100.0
```

```
      TERM=1.0+FLOATI
      DO 180 N=1,YEARS
         SUM=SUM+(V(N,VALU))/TERM**FLOAT(N)
  180  CONTINUE
      TERM=(1.0+FLOATI)
      COEF=(FLOATI*(TERM)**YEARS)/(TERM)**(YEARS-1)
      DX=COEF*SUM
C     TELL INDEX VALUE
      WRITE(IOUT,2110)(COMPNT(J,VALU),J=1,6),DX
C     WRITE TO SCRATCH
      WRITE(20,2280) FOREST,FIRE,YEARS,RATE,DX,(COMPNT(J,VALU)
,J=1,6)
C     ANOTHER RATE?
      WRITE(IOUT,2120)
      READ(IIN,2130)ANS
      IF(ANS.EQ.'Y') GO TO 160
C     ANOTHER PERIOD?
      WRITE(IOUT,2140)
      READ(IIN,2130)ANS
      IF(ANS.EQ.'Y') GO TO 150
C     ANOTHER FIRE INTENSITY?
      WRITE(IOUT,2150)
      READ(IIN,2130)ANS
      IF(ANS.EQ.'Y') GO TO 140
      WRITE(IOUT,2160)
C     ANOTHER ECOSYSTEM COMPONENT?
      READ(IIN,2130)ANS
      IF(ANS.EQ.'Y') GO TO 40
C     OUTPUT SUMMARY
      REWIND 20
      WRITE(IOUT,2290)
  190 READ(20,2290,END=200)FOREST,FIRE,YEARS,RATE,DX,(FORMAT(K),
K=1,6)
      WRITE(IOUT,2300) FOREST,FIRE,YEARS,RATE,DX,(FORMAT(K),K=
1,6)
      GO TO 190
  200 CLOSE(UNIT=1)
      CLOSE(UNIT=2)
      CLOSE(UNIT=20)
      STOP
 2000 FORMAT(26H BURN!  FOREST TYPES ARE! //
     119H   1-PONDEROSA PINE,23X,19H2-MIXED CONIFER    /
```

```
     219H   3-PINYON-JUNIPER)
2010 FORMAT(/52H ENTER NUMBER OF FOREST TYPE YOU WISH TO
    1 EVALUATE   ,$)
2020 FORMAT(I)
2030 FORMAT(25H **ERROR** FOREST OPTION ,I1,23H IS NOT YET IMPL
IMENTED)
2040 FORMAT(33H **ERROR** YEARS MUST BE POSITIVE)
2050 FORMAT(/28H FIRE INTENSITY OPTIONS ARE://
    132H   1- LESS THAN 5,000 BTU/SEC/FT,9X,
    229H 2- AT LEAST 5,000 BTU/SEC/FT/
    328H   3- OVER 10,000 BTU/SEC/FT)
2060 FORMAT(/41H ENTER NUMBER OF FIRE INTENSITY OPTION   ,$)
2070 FORMAT(18H **ERROR** OPTION ,I1,20H NOT YET IMPLIMENTED)
2080 FORMAT(/40H POST-BURNING EVALUATION PERIOD IN YEARS
    11X,18H(CR GIVES:20) ?   ,$)
2090 FORMAT(/44H DISCOUNT RATE IN PERCENT (CR GIVES: 5) ?   ,$)
2100 FORMAT(44H **ERROR** RATE MUST BE BETWEEN ZERO AND 100)
2110 FORMAT(//18H IMPACT INDEX FOR ,6A5,
    14H IS ,F5.1)
2120 FORMAT(//52H ANOTHER DISCOUNT RATE(YES OR NO, CR GIVES: NO
) ?   ,$)
2130 FORMAT(A1)
2140 FORMAT(53H ANOTHER POST-BURNING EVALUATION PERIOD(YES OR N
O, CR
    11X,15HGIVES: NO) ?   ,$)
2150 FORMAT(53H ANOTHER FIRE INTENSITY(YES OR NO, CR GIVES: NO)
 ?   ,$)
2160 FORMAT(58H ANOTHER ECOSYSTEM COMPONENT(YES OR NO
    1, CR GIVES: NO) ?   ,$)
2170 FORMAT(80A1)
2180 FORMAT(6A5)
2190 FORMAT(37H ECOSYSTEM EVALUATION COMPONENTS ARE://
    126H   1- VEGETATIVE COMPONENT,16X,
    221H2- WILDLIFE COMPONENT/
    326H   3- HYDROLOGIC COMPONENT//
    450H ENTER NUMBER OF COMPONENT YOU WISH TO EVALUATE
    5   ,$)
2200 FORMAT(16H ATTRIBUTES ARE://
    135H   1- PONDEROSA PINE TREE MORTALITY,8X,
    230H2- PONDEROSA PINE REGENERATION/
    343H   3- PRODUCTION OF HERBACEOUS UNDERSTORIES//
    450H ENTER NUMBER OF ATTRIBUTE YOU WISH TO EVALUATE   ,$)
```

```
241           2210 FORMAT(16H ATTRIBUTES ARE:/
242               133H   1- MULE DEER (SUMMER/FALL USE),9X,
243               232H2- MULE DEER (WINTER/SPRING USE)/
244               327H   3- ELK (SUMMER/FALL USE),15X,
245               426H4- ELK (WINTER/SPRING USE)/
246               532H   5- ABERT SQUIRREL POPULATIONS,10X,25H6- COTTONTAIL P
247               6OPULATIONS/
248               731H   7- RODENT POPULATIONS (LIST),11X,34H8- NONGAME BIR
249               8D POPULATIONS (LIST)/
250               938H   9- BROWSE AND FORAGE SPECIES (LIST),3X,
251               123H10- GROUND COVER (LIST)//
252               250H ENTER NUMBER OF ATTRIBUTE YOU WISH TO EVALUATE   ,$)
253           2220 FORMAT(13H RODENTS ARE:/
254               115H   1- DEER MICE,27X,19H2- GROUND SQUIRRELS/
255               215H   3- CHIPMUNKS//
256               347H ENTER NUMBER OF RODENT YOU WISH TO EVALUATE   ,$)
257           2230 FORMAT(19H NONGAME BIRDS ARE:/
258               115H   1- ALL BIRDS,27X,31H2- TREE FOLIAGE SEARCHING BIRDS/
259               227H   3- TIMBER GLEANING BIRDS,15X,30H4- GROUND-BRUSH
260               3 FORAGING BIRDS/
261               423H   5- FLYCATCHING BIRDS,19X,24H6- TIMBER DRILLING BIRDS
/
262               530H   7- AERIAL FLYCATCHING BIRDS//
263               654H ENTER NUMBER OF NONGAME BIRDS YOU WISH TO EVALUATE   ,
$)
264           2240 FORMAT(31H BROWSE AND FORAGE SPECIES ARE:/
265               120H   1- PONDEROSA PINE,22X,12H2- BUCKBRUSH/
266               215H   3- DEERVETCH,27X,11H4- FLEABANE/
267               315H   5- BUCKWHEAT//
268               466H ENTER NUMBER OF BROWSE AND FORAGE SPECIES YOU WISH
269               5 TO EVALUATE   ,$)
270           2250 FORMAT(34H GROUND COVER CHARACTERISTICS ARE://
271               121H   1- FORB BASAL AREA,21X,19H2- GRASS BASAL AREA/
272               212H   3- LITTER,30X,14H4- BARE GROUND/
273               310H   5- ROCK//
274               469H ENTER NUMBER OF GROUND COVER CHARACTERISTICS YOU
275               5 WISH TO EVALUATE   ,$)
276           2260 FORMAT(16H ATTRIBUTES ARE:/
277               116H   1- STREAMFLOW,25X,23H2- WATER QUALITY (LIST)//
278               250H ENTER NUMBER OF ATTRIBUTE YOU WISH TO EVALUATE   ,$)
279           2270 FORMAT(32H WATER QUALITY CONSTITUENTS ARE:/
280               113H   1- CALCIUM,29X,12H2- MAGNESIUM/
```

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281                212H    3- SODIUM,30X,11H4- CHLORIDE/
282                313H    5- SULFATE,29X,14H6- BICARBONATE/
283                414H    7- FLOURIDE,28X,10H8- NITRATE/
284                58H    9- PH,33X,23H10- TOTAL SOLUBLE SALTS/
285                629H   11- ELECTRICAL CONDUCTIVITY//
286                756H ENTER WATER QUALITY CONSTITUENT YOU WISH TO EVALUATE
287                8    ,$)
288           2280 FORMAT(4I3,F4.1,6A5)
289           2290 FORMAT(////9H SUMMARY:/18X,20HEVALUATION  DISCOUNT/
290               17H FOREST,3X,4HFIRE,6X,6HPERIOD,6X,4HRATE,4X,6HIMPACT/
291               26H  TYPE,2X,9HINTENSITY,2X,7H(YEARS),4X,
292               39H(PERCENT),2X,5HINDEX,6X,9HATTRIBUTE//)
293           2300 FORMAT(3X,I1,7X,I1,9X,I2,10X,I2,6X,F4.1,5X,6A5)
294                END
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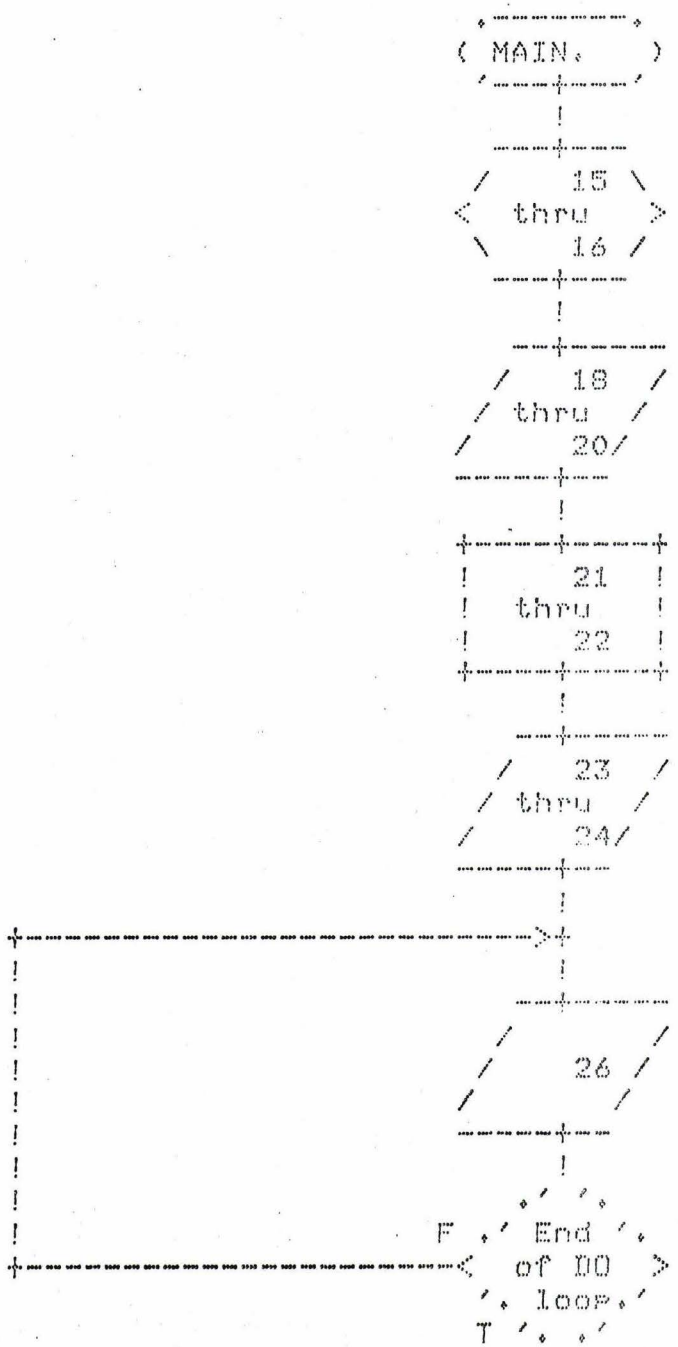
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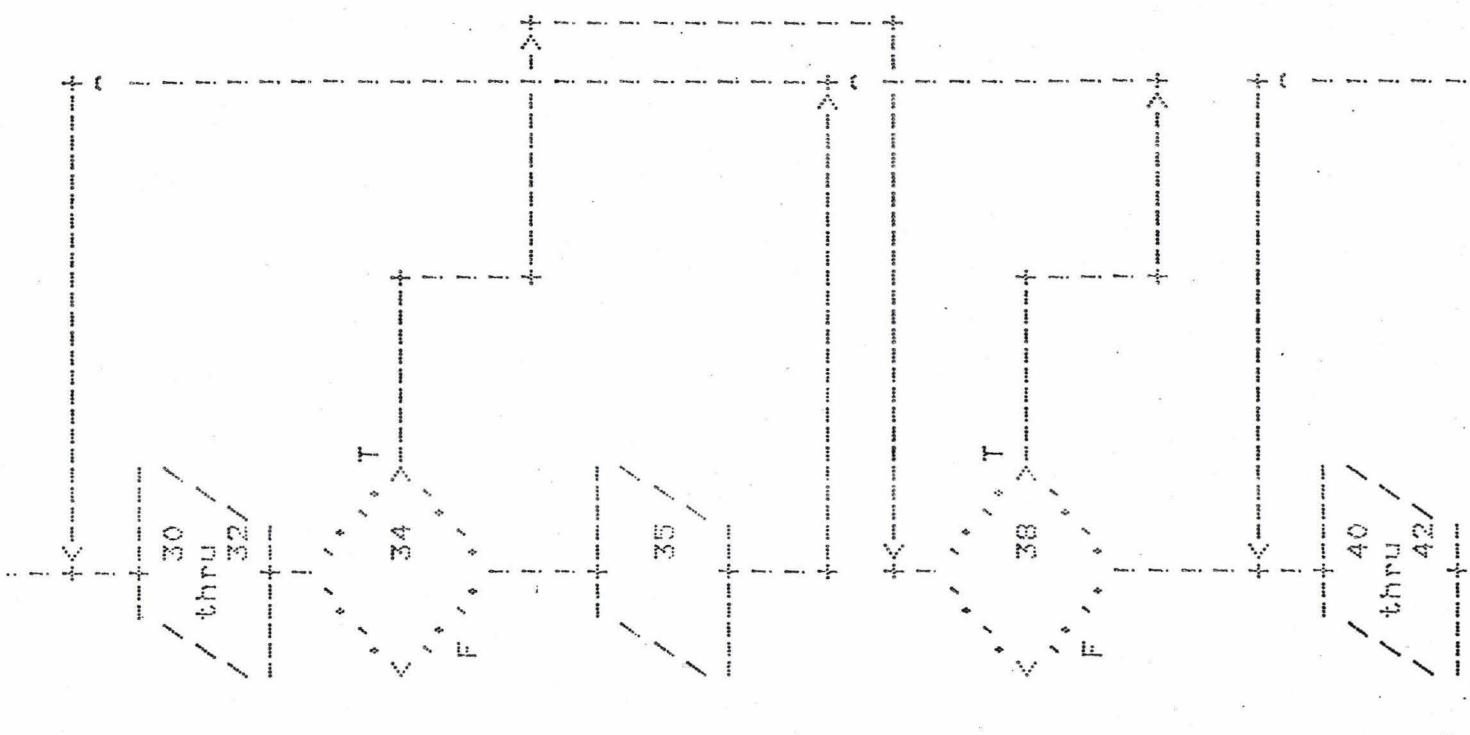
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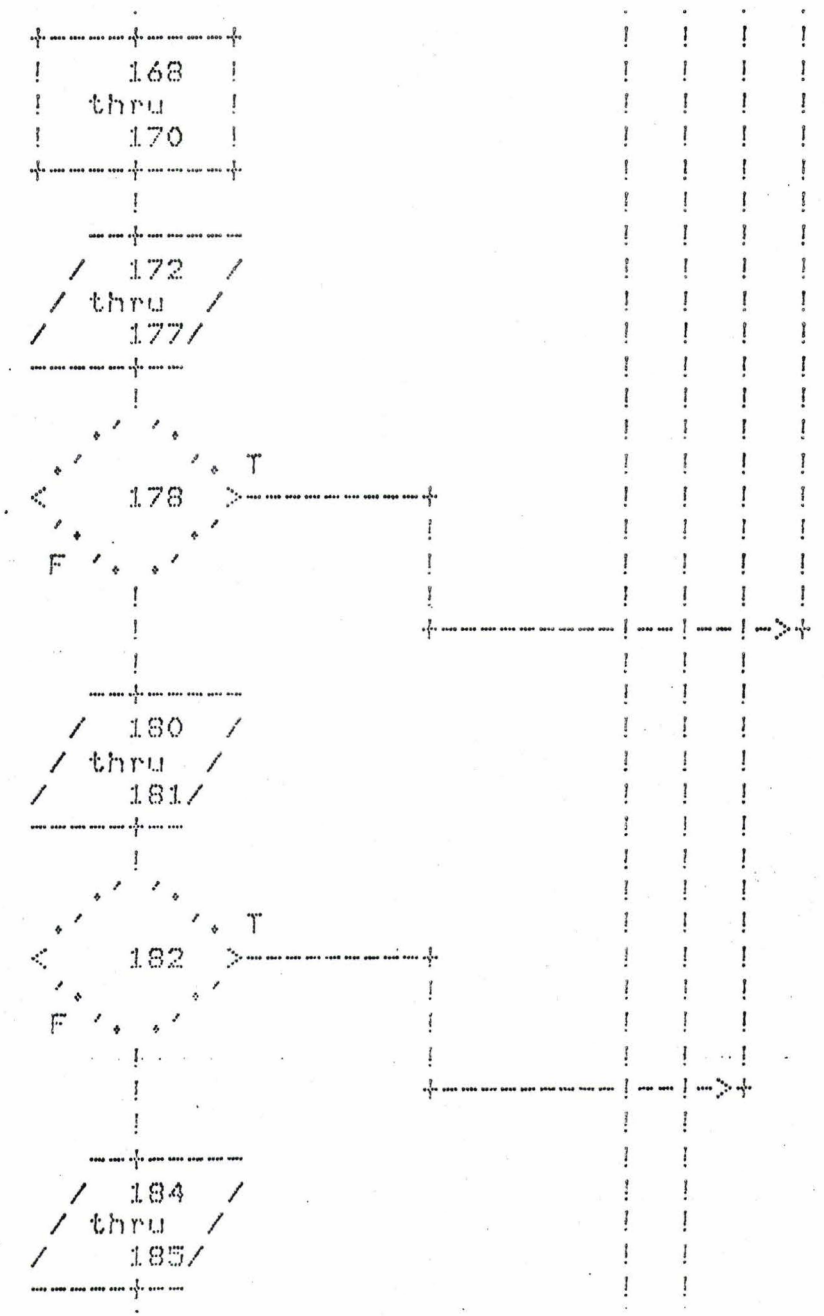
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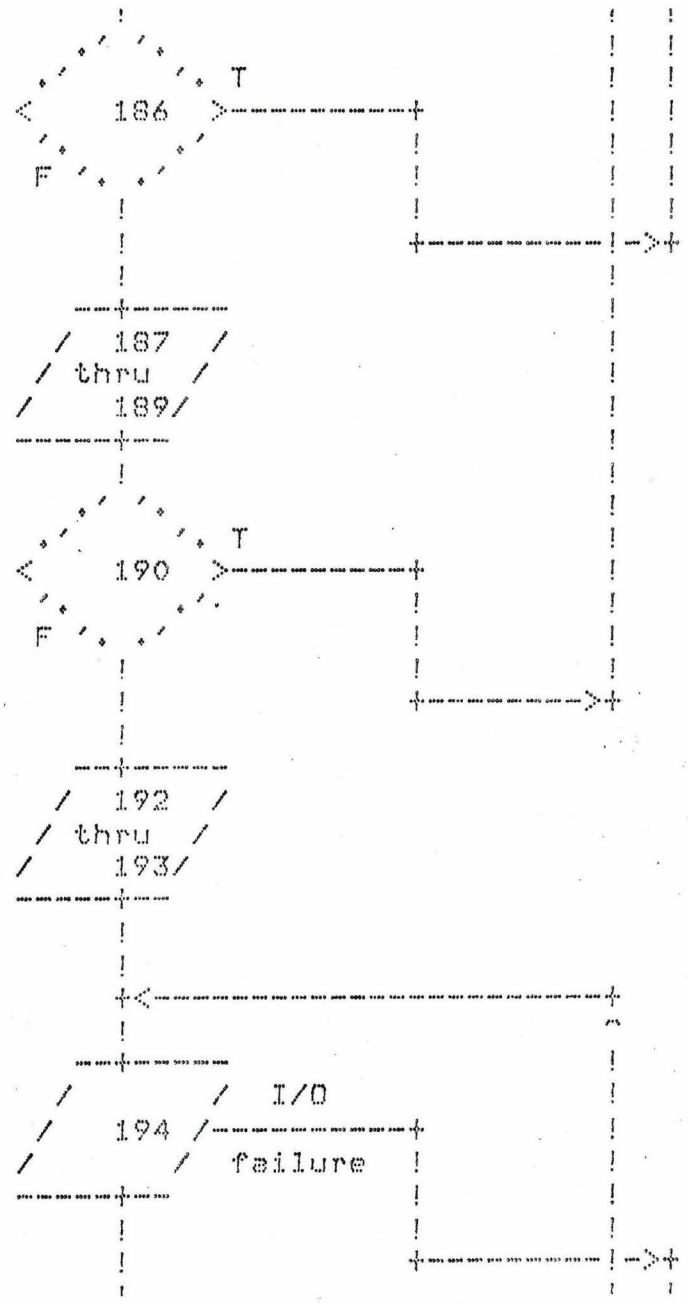
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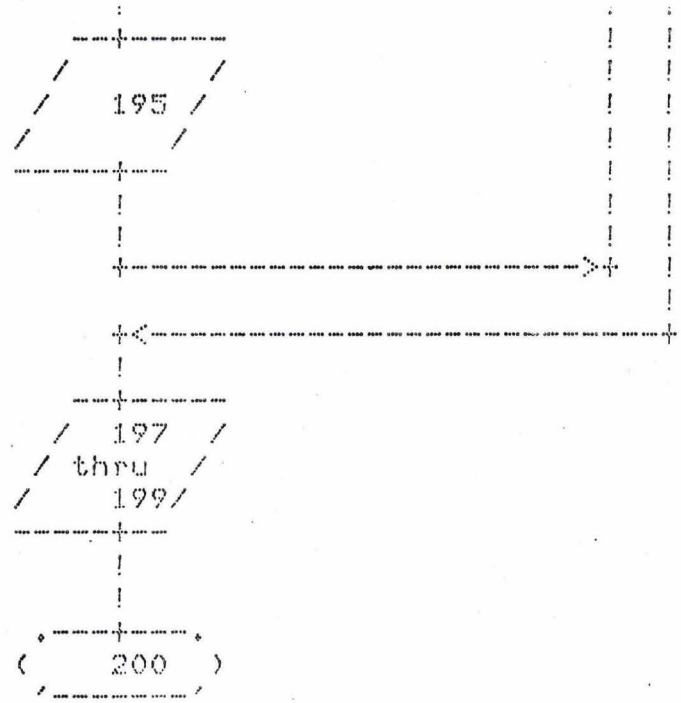
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APPENDIX B

LISTING OF FILE BURN.001

MULE DEER (SUMMER/FALL USE)
MULE DEER (WINTER/SPRING USE)
ELK (SUMMER/FALL USE)
ELK (WINTER/SPRING USE)
ABERT SQUIRREL POPULATIONS
COTTONTAIL POPULATIONS
BROWSE AND FORAGE SPECIES (LIST)
GROUND COVER (LIST)
PONDEROSA PINE
BUCKBRUSH
DEERVETCH
FLEABANE
BUCKWHEAT
FORB BASAL AREA
GRASS BASAL AREA
LITTER
BARE GROUND
ROCK
ALL BIRDS
TREE FOLIAGE SEARCHING BIRDS
TIMBER GLEANING BIRDS
GROUND BRUSH FORAGING BIRDS
FLYCATCHING BIRDS
TIMBER DRILLING BIRDS
AERIAL FLYCATCHING BIRDS
DEER MICE
GROUND SQUIRRELS
CHIPMUNKS
STREAMFLOW
CALCIUM
MAGNESIUM
SODIUM
CHLORIDE
SULFATE
BICARBONATE
FLUORIDE
NITRATE
PH
TOTAL SOLUBLE SALTS
ELECTRICAL CONDUCTIVITY
PONDEROSA PINE TREE MORTALITY
PONDEROSA PINE REGENERATION
HERBAGE PRODUCTION

APPENDIX C

LISTING OF FILE BURN.002

```
(20(F5.2,1X))
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